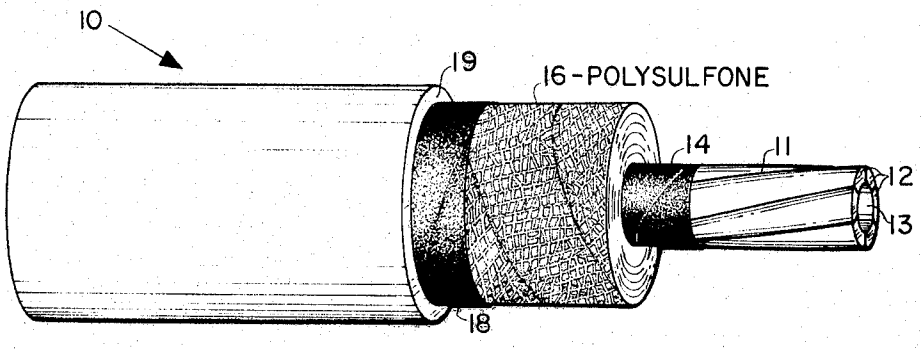
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HIGH VOLTAGE CABLES INSULATED WITH POLYSULFONE TAPES

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HIGH VOLTAGE CABLES INSULATED WITH POLYSULFONE TAPES

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ABSTRACT OF THE DISCLOSURE

High-voltage cables of the type known as pipe-type cables or gas-filled cables and paper-lead cables are insulated with polysulfone film tapes instead of paper tapes.

Cross-reference to related applications

This application is a continuation-in-part of our copending application Serial No. 531,238, filed March 2, 1966, now abandoned.

Background of the invention

It has long been known to insulate a high-voltage cable with layers of oil-saturated paper and enclose it in a sheath filled with a dielectric fluid such as hydrocarbon oil or pressurized, inert gas. The sheath is commonly a lead or aluminum extrusion, which may be reinforced with tension wires or tapes when the cable is intended to be operated at high pressure. The sheath may also take the form of a rigid pipe such as the steel pipe used for pipe-type cables.

There is an interest in operating electric cables at increasingly high temperatures and voltages, 125° C. being considered commercially for the former and 500 kv. for the latter. For these high values it has been suggested to use different synthetic insulating tapes instead of the paper tapes currently in use. Thus Thompson et al., in Patent 3,105,872, discloses the use of embossed polycarbonate tapes, Olds, in Patent 3,077,510 discloses the use of polyethylene tapes, Kang, in Patent 3,077,514, discloses the use of a number of tape materials including polypropylene, polybutylene, polystyrene, and polytetrafluorethylene.

While the usefulness of any synthetic material for insulating high-voltage cables might be judged to be predictable from its published properties, in practice this is far from true. Most materials that have been suggested for use as high-voltage insulating tapes have proven to be unsuitable. This is witnessed by the fact that although synthetic plastic films have been on the market for many years, paper is still the only material in commercial use for building up wrapped-insulation power cables.

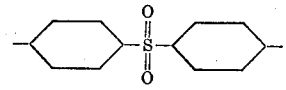
One important requirement for electric cables is flexibility. This presents a particular problem in the case of high-voltage cables because the walls of insulation must be relatively thick in order to provide the required dielectric strength. The flexibility of tape-insulated conductors depends largely upon the fact that the layers can slide upon each other, and when this is prevented by friction, the cable, if the insulation wall is thick enough, becomes rod-like and unmanageable. This is a particular problem at the point in cable manufacture when the cable is taken up from the taping machine onto a reel for storage and further processing. It has been suggested that the insulating tapes should be lubricated with oil prior to the taping operation, but this involves additional operations and special handling that adds to the cost. Furthermore, the oil used for high-voltage cables is normally deaerated and dried before being introduced into the cables. When oil is introduced on the surface of the tapes it is bound to contain dissolved air and moisture.

Another important requirement for high-voltage cable tapes is that they must be compatible over periods of

years at high temperatures, with the other elements of the cable such as the copper or aluminum conductor, the insulating oil or gas, and the sheathing and shielding materials.

Summary of the invention

We have now discovered that a superior high-voltage cable will result from the use of polysulfone insulating tape wherein the polysulfone comprises a recurrent



linkage and that, unexpectedly, such a cable will bend readily upon removal from the taping machine even without prelubrication of the tape, and even when the tape layers have a combined wall thickness of about ½ inch or greater. We have invented a high-voltage cable comprising a conductor preferably of copper because of its high conductivity, a plurality of layers of polysulfone tapes, preferably embossed, surrounding the conductor, a tubular sheath surrounding the layers and a dielectric fluid such as a hydrocarbon oil or pressurized gas within the sheath.

Brief description of the drawing

A more thorough understanding of our invention can be gained from the appended drawing. In the drawing the figure shows a cut-away perspective view of the end of a lead-sheathed cable made in accordance with our invention.

Description of the preferred embodiments

The cable indicated generally by the numeral **10** has a copper conductor **11**, stranded from a plurality of copper wire segments **12** in a known manner, to form an internal channel **13** for the passage of dielectric fluid. A semiconducting strand shielding **14** is wrapped around the conductor **11** and a plurality of insulating layers of polysulfone tapes **16** are wrapped around the strand shielding. The tapes have been embossed in a random pattern of hills and valleys in the manner of Patent 3,105,872. Over the tapes **16** there is wrapped a semiconducting shielding **17**, and a lead sheath **18** has been extruded over the shielding. The sheath **18** is filled with an aliphatic mineral oil that fills all the available space in the cable and wets the surfaces of the tapes. When the oil is pressurized, this type of cable is known as oil-filled cable. Our invention, however, is not limited to oil-filled cables but may also be applied to the type known as solid cables when its conductor is not hollow and the oil is not pressurized, and to cables where oil channels are extended into the inner surface of the sheath rather than being formed in the conductor. It may also be applied to 3-conductor cables where the three phase conductors are included within a single sheath and the shielding **17** is reinforced with copper tapes of high current capacity. If its three conductors are included within a steel pipe the cable is known as a pipe-type cable and the oil is usually maintained under high pressure such as 200 p.s.i. Instead of oil, the sheath **18** may enclose a pressurized gas such as nitrogen which may be reinforced by a high dielectric strength fluorocarbon of which several types are known.

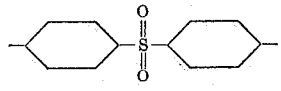
In each of these known general constructions, however, our cable is characterized by the novel use of polysulfone tapes.

A polysulfone tape suitable for the practice of our invention is sold by Union Carbide Corporation under

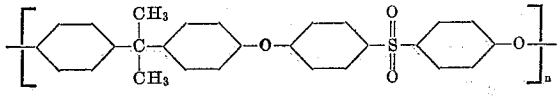
the designation Bakelite P–1700 with the following properties:

Property	ASTM Test Number	Value
Specific Gravity	D 792	1.24.
Clarity		Transparent.
Hardness	D 785	M 68 R 122.
Water Absorption	D 570	0.22% (24 hr.).
Flamability	D 635	Self-extinguishing.
Heat Deflection	D 648	345° F. at 264 p.s.i.
Coef. of Expansion	D 695	3.1×10^{-5}/° F.
Tensile Str. at Yield	D 638	10,200 p.s.i.
Total Elongation	D 638	50–100%.
Flexural Modulus at 72° F	D 790	0.390×10^{5} p.s.i.
Flexural Modulus at 300° F	D 790	0.320×10^{5} p.s.i.
Notched Izod Impact	D 256	1.3 ft.-lb./inch.
Unnotched Izod Impact		Over 60 ft.-lb./inch.
Dielectric Constant	D 150	3.14 at 72° F., 60 c.p.s.
Do	D 150	3.10 at 72° F., 10^{6} c.p.s.
Do	D 150	2.8 at 300° F., 60 c.p.s.
Do	D 150	2.8 at 300° F., 10^{6} c.p.s.
Dissipation Factor	D 150	0.0008 at 72° F., 60 c.p.s.
Do	D 150	0.0056 at 72° F., 10^{6} c.p.s.
Do	D 150	0.0015 at 300° F., 60 c.p.s.
Do	D 150	0.0025 at 300° F., 10^{6} c.p.s.
Dielectric Strength	D 149	425 volts/mil.
Volume Resistivity	D 257	5×10^{16} ohm-cm.
Arc Resistance	D 495	122 sec.
Acid Resistance	D 495	No effect.
Alkali Resistance	D 495	Do.
Aliphatic Hydrocarbons	D 495	Do.
Aromatic Hydrocarbons	D 495	Partially soluble or swells.
Chlorinated Hydrocarbons	D 495	Soluble.

The polysulfone molecule is characterized by having a recurrent



linkage and the above-mentioned preferred polymer has the structure



where n=50–80.

The method of making the preferred sulfone polymer is described in Belgium Patent 650,476. In this method 11.42 g. of 2.2 bis (4-hydroxyphenyl) propane, 13.1 g. of potassium hydroxide, 50 ml., of dimethyl sulfoxide and 6 ml. of benzene are purged with nitrogen and refluxed 3 to 4 hours in an inert atmosphere. Water is continuously eliminated as the benzene azeotrope, enough of the latter being drawn off to obtain a reflux mixture at 130–135° C. consisting of the dipotassium salt of 2,2-bis (4-hydroxyphenyl) propane and dimethyl sulfoxide essentially free from water. The mixture is cooled and 14.35 g. of 4,4′ dichlordiphenyl sulfone are added followed by the by the addition of 40 ml. of anhydrous dimethyl sulfoxide, all under a nitrogen atmosphere. The mixture is heated to 130° C. and agitated well for 4–5 hours while being held between 130–140° C.

The viscous orange solution is poured into 300 ml. of water rapidly stirred in a Waring Blender and the finely divided white powder is filtered and dried in a vacuum oven at 110° C. for 16 hours.

Films are prepared by dissolving in tetrachlorethane and washing with diulte acetic acid and then with water, reprecipitating by pouring into methanol, filtering, and drying in vacuum at 70° C., and compression molding the powder at 270° C.

Electric cables, particularly high-voltage cables, are expected to operate for many years without trouble and for this reason the elements making up the cable must be compatible and not react with each other, even slowly,

or at elevated temperatures. It is known that sulfur reacts with copper and for this reason the insulating oils of high-voltage cables must be refined free from any traces of sulfur. It is surprising, therefore, to find that a polysulfone tape can be employed with copper conductors over long periods at elevated temperatures, without corroding the copper.

EXAMPLE 1

Bright copper conductors were wrapped lith Bakelite P–1700 polysulfone tape and immersed in Sun #6 mineral oil for 4 days at 121° C. At the end of this period, the tapes were removed and the copper was found to have remained bright.

EXAMPLE 2

A cable was insulated in accordance with the figure with the conductor **11** having an outside diameter of 1.800 inch, a diameter over the strand shielding **14** of 1.816 inch, and 104 unlubricated layers of embossed tapes of Bakelite P–1700 polysulfone were wrapped over the strand shielding as follows:

Tape Gage Before Embossing, mils	Direction of Lay	Number of Layers
3	Left hand	10
4	Right hand	10
4	Left hand	10
5	Right hand	10
6	Left hand	8
6	Right hand	7
6	Left hand	7
8	Right hand	10
8	Left hand	10
8	Right hand	10
8	Left hand	1

Two 25 mil intercolated polyester shielding tapes were then applied with a left hand lay so that the overall diameter was 3.260 inches. This cable core was taken up from the taping machine onto a cable reel without lubrication and without difficulty in bending. Examination showed the tapes to be entirely free from creases and buckling.

We have invented a new and useful high-voltage cable for which we desire an award of Letters Patent.

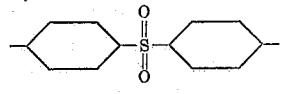
What is claimed is:

1. A high-voltage electric cable comprising:

(A) a conductor,

(B) a plurality of layers of polysulfone tape surrounding said conductor,

(a) said polysulfone comprising a recurrent



linkage, and

(b) said layers having a combined wall thickness of at least about ½ inch,

(C) a tubular sheath surrounding said layers, and

(D) a dielectric fluid within said sheath.

2. The cable of claim **1** wherein said tape is embossed.

3. The cable of claim **1** wherein said fluid is a hydrocarbon oil.

4. The cable of claim **1** wherein said conductor is copper.

References Cited

UNITED STATES PATENTS

3,077,514 2/1963 Kang ..... 174—25 X

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